The present and future effects of ground fires on forest carbon stocks, metabolism, hydrology and economic value in Amazonia and the Cerrado

Progress Report

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Introduction

Fire is the single greatest threat to the integrity of tropical forest ecosystems. And yet, the scientific community has little mechanistic understanding of how forests catch fire, and how burning affects the forest. The purpose of this project is to improve our ability to predict the areal extent of understory fires in Amazonian forests, and to measure the effect of these fires on forest biomass, evapotranspiration, run-off, timber stocks, and game populations. In the cerrado, our objective is to measure the influence of fire frequency on savanna metabolism, biomass, evapotranspiration, and run-off. Our progress in achieving these goals is summarized in this report.

Objective 1: Improvements in biophysical components of forest fire prediction model.

During this period, we completed the experimental fires that are needed to fully parameterize the forest fire prediction model. We have now conducted a total of approximately **550 experimental fires** divided among dense, tall forests interspersed with liana forest (Paragominas, FLONA Tapajós), transitional forests (Santana do Araguaia), and open forests interspersed with bamboo (Acre). For each fire, we measure the rate of spread of a kerosene-ignited fire during a 4-minute period and make accompanying measurements of fine fuel load, fuel moisture, leaf area index, soil moisture content, relative humidity (air) and air temperature.   The determinants of fire spread are far more complex than previously reported in the literature. For example, the

accumulation of smoke in the atmosphere can in a negative feedback with forest floor flammability. By blocking solar radiation, the air temperature does not climb as much during the day and relative humidity remains high; the fine fuel layer dries more slowly under these conditions, and flammability declines.

Objective 2: Improvements in the socio-economic component of the model.

Currently, RisQue estimates forest fire risk by calculating forest fire vulnerability (see Objective 1) and using NOAA/AVHRR-derived "hot pixel" distribution as a proxy for the probability that fire-vulnerable forests will ignite. Our LBA grant is allowing us to replace this hot pixel proxy with an econometric model, that we hope will allow us to estimate the risk of ignition on the basis of rural census data. We hope that this model will also allow us to test the impact of policy scenarios (agricultural credit, policing activities, taxation, etc.) on fire occurrence. To develop this economic model, we have embarked on an extensive field study of fire economics, through interviews of a wide range of rural producers, from subsistence farmers to large-scale ranchers. During this grant period, we further **tested the questionnaire through interviews conducted in two regions of Amazonia: Santarem (20) and Acre (25).** This work will expand to ~500 interviews in 2001.   A Brazilian economist and Professor at the Federal University of Pará (Larissa Chermont) is developing this work as her PhD dissertation, with assistance from project collaborator Joshua Bishop of the International Institute of Environment and Development (IIED).

Perhaps the single best predictor of ignition sources for fire-vulnerable forests is proximity to roads. The Brazilian government has embarked on an ambitious road-building and asphalting program that includes more than 6000 km of newly asphalted and constructed roads in the Amazon. We conducted an **analysis of the rate of deforestation along major roads of the Brazilian Amazon** by assembling a composite map of land cover from the Pathfinder database, then determining the percentage of forest lost along paved vs. unpaved roads (Figure 1). Within the first 20 years following road paving, from 28 to 58% of the forest is clear-cut. Without paving, the highest rate of deforestation that we found was 8%. These results were published in Portuguese in a report on the IPAM website and were featured as the front-page story in the Folha de São Paulo, and in an 8-page cover story of Time Magazine (Latin America edition) and a 2-page story in Time Magazine (US Edition).

% Deforested Along Amazon Highways
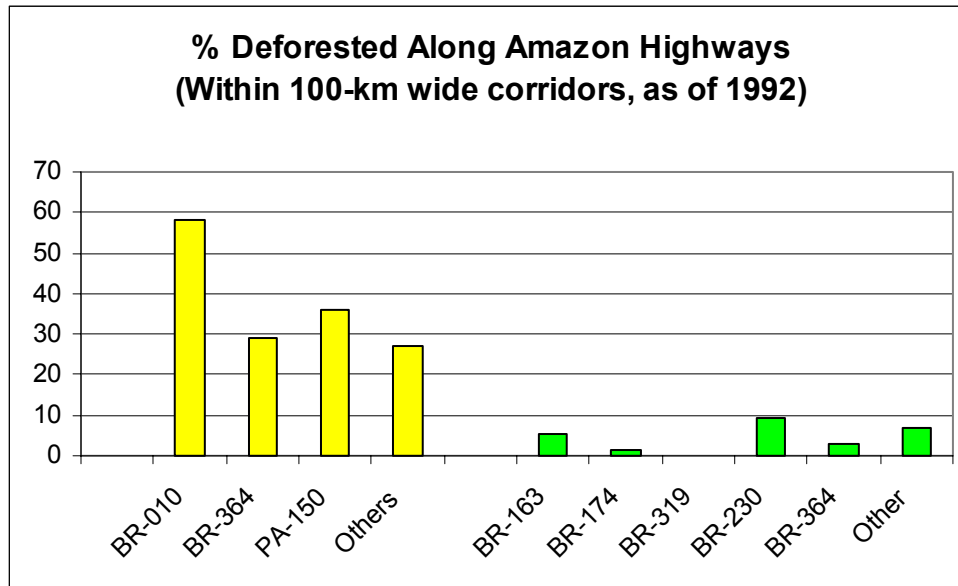**(Within 100-km wide corridors, as of 1992)**

Figure 1. Percent deforestation along Brazilian Amazon highways (50 km either side), determined from 1991/92 Pathfinder dataset.   (Nepstad et al., in press).

Objective 3. Effects of understory fires on Amazon forest biomass, hydrology and economic value.

Understory fires kill trees, affecting forest biomass, forest evapotranspiration, and the forest mammal populations that are an important source of animal protein for subsistence farmers. During severe droughts, carbon emissions from forest understory fires may be equivalent to, or greater than, emissions from deforestation burning (Nepstad et al. 1999--Nature). We have now **completed our study of the effects of understory fires on forest biomass and on mammal populations** through a chronosequence study near Paragominas, in which we are measuring the aboveground biomass and censusing mammal populations in forests that are unburned, recently burned, and that burned 5-8 years ago. The biomass estimates reveal much more variability than our earlier studies (Cochrane et al. 1999). It appears that most mammal species suffer substantial declines immediately following fire, but some species, such as white-lipped peccaries and brocket deer, recover with time.

We have **excavated 11 soil shafts to 12 meters depth in the Tapajós National Forest and Caxiuana National Forest, and instrumented them with TDR soil moisture sensors**. These measurements will allow us to estimate evapotranspiration and soil drainage in the immediate vicinity of the eddy correlation tower (km 67, two shafts), and in control and treatment plots of our rainfall exclusion experiment (n=3 per plot). Three shafts were excavated at Caxiuana.   We are currently doing a calibration of these sensors for the soils of the Tapajós forest.

In the rainfall exclusion experiment, which is now an official component of LBA Ecology, we are also measuring: **litterfall, forest floor decomposition, tree stem**

growth (n=1,100), Granier sapflow, leaf water potential (biweekly, canopy), quantitative leaf phenology (n=250 trees with 5 branches per tree), canopy photosynthesis, soil respiration, fine and coarse root biomass, and leaf area index.

We prepared a **50 x 50 m area for experimental burning in the Tapajós National Forest** this year. With the large amount of rain this year, we were forced to accelerate forest floor driving through manual thinning of the forest canopy. Even with this thinning, however, fuel moisture content did not drop sufficiently to allow ignition.

We have completed a first draft of our **analysis of the economic effects of Amazon fire**, including smoke-related illnesses, airport closures, electric transmission interruptions, damages to land investments, and the emission of carbon, in collaboration with economists of the Institute de Pesquisa Economica Aplicada (IPEA), who are the foremost authorities on environmental valuation in Brazil. One of the more noteworthy findings was the large number of deaths (several hundred) resulting from respiratory ailments provoked by fire during years of severe drying.

Objective 4. Effects of fire regime on cerrado

Unlike Amazon forests, the savanna woodlands of the somewhat drier Cerrado region may have burned every decade or so even before this region was occupied by modern civilization. One important ecological effect of this occupation has been to increase the frequency of this burning. Our LBA grant is allowing us to measure the effect of this increased burning frequency on cerrado vegetation. We are accomplishing this by comparing the exchange of carbon dioxide and water vapor with the atmosphere in cerrados that have burned with different frequencies.

After considerable delays encountered in the importation of instruments, we **established two new eddy correlation towers near Brasilia, in the IBGE reserve**. One tower is located in grass-dominated *campo sujo* last burned in August 1999. The other was installed in a very similar *campo sujo* burned in June 2000. Tower measurements began May 2000, and are accompanied by soil water measurements to 4 m depth. These measurements are accompanied by a similar eddy correlation and soil moisture balance comparison of dense cerrado vegetation with differing fire histories being conducted by H. and A. Miranda at the Aguas Emendadas reserve. At the Agua Emendadas site, **we also installed 3 shafts to 8 meters depth, that are equipped with TDR soil moisture sensors.**

Our rainfall exclusion experiment conducted at the IBGE reserve (coordinated by Dr. Carlos Klink, UnB) is providing data on litterfall, fine root biomass and distribution, soil respiration, quantitative phenology, leaf water potential (pre-dawn), and leaf area index.

Scientific publications completed this far with support from this grant

Carvalho, G., A. C. Barros, P. Moutinho, D. Nepstad. In press. Amazonia at the crossroads. Nature

Cochrane, M., A. Alencar, C. Souza, D. Nepstad, P. Lefebvre, E. Davidson.) Positive feedbacks in the fire dynamic of closed canopy tropical forests. *Science* 284:1832-1835

Nepstad, D, A. Veríssimo, A. Alencar, C. Nobre, P. Lefebvre, P. Schlesinger, C. Potter, P. Moutinho, E. Lima, M. Cochrane, Vanessa Brooks. 1999. Large-scale impoverishment of Amazonian forests by logging and fire. *Nature.* 398:505-508.

Nepstad, D., A. Moreira, A. Alencar. Flames in the Rainforest: Origins, Impacts and Alternatives to Amazonian Fire. World Bank. 140-page book in English and Portuguese. (A Floresta em Chamas: Origens, Impactos e Prevenção de Fogos na Amazônia)

Nepstad, D., J. P. Capobianco, A. C. Barros, G. Carvalho, P. Moutinho, U. Lopes, P. Lefebvre, Michael Ernst. "Avança Brasil: Os Custos Ambientais para a Amazônia" (Avança Brasil: The Environmental Costs for Amazonia". Instituto de Pesquisa Ambiental da Amazônia, Instituto Socio-Ambiental. (http://www.ipam.org.br) 23 pp.

Nepstad, D., A. Veríssimo, P. Moutinho, C. Nobre. 2000. O empobrecimento oculto da floresta Amazônica. (The hidden impoverishment of Amazon forests.). *Ciencia Hoje* 27(157): 70-73.

Nepstad, D., G. Carvalho, A. C. Barros, A. Alencar, J. P. Capobianco, J. Bishop, P. Moutinho, P. Lefebvre, U. L. Silva Jr.   In press. Road paving, fire regime feedbacks, and the future of Amazon forests.   Forest Ecology & Mgt.

Popular publications featuring LBA-supported research:

Time magazine cover story, Sept. 25, 2000. "The Amazon Tinderbox". Latin American Edition.

Time magazine, October 2000. Two pages.

Folha de São Paulo. Cover page headline story, March 23, 2000, describing analysis of road effects on deforestation/burning.

Folha de São Paulo, December 1999 (?) 4-page story on rainfall exclusion experiment.

Veja magazine, November 22, 2000. Cover story, including one page description of rainfall exclusion experiment.

Television:

Rainfall exclusion experiment topic of two national news stories in Brazil.
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Brazilian students conducting theses with support from our LBA grant:

Larissa Chermont began PhD in natural resource economics at Imperial College, London, in September 1999. She is conducting the household economic study as her dissertation. (LBA paid tuition and fees first year; CNPq provided her with a fellowship for the remaining years of study)

Alexandre Barbosa Santos, aluno de doutorado no programa de pos-graduacao em Ecologia, Depto. de Ecologia, UnB.

Oswaldo Carvalho Jr. Will apply to the INPA doctoral program. His thesis is the field study of fire effects on biomass and game populations. (LBA supporting his research expenses.)

Gina Cardinot has applies to PhD program at UFRio de Janeiro. Her thesis will be the canopy water relations work she is conducting in the rainfalle exclusion experiment, Tapajós.

Luciana Monaco (MSc), received an LBA – CNPq fellowship to work in the rainfall exclusion experiment in the Tapajós.

Lace Mediros Breyer, PhD student, Ecology, UnB (eddy correlation) doutorado no programa de pos-graduacao em Ecologia, Depto. de

Sergio Viana de Andrade. Undergraduate student, forestry, UnB. (Soil moisture).

Carlos Alberto Nobre Quesada, undergraduate student, forestry, UnB

An addition 6 undergraduate students from Belém and Santarem are doing internships within our LBA research.